US011043749B2

(12) **United States Patent**
Wu et al.

(10) **Patent No.: US 11,043,749 B2**
(45) **Date of Patent: Jun. 22, 2021**

(54) **ANTENNA STRUCTURE**

(71) Applicant: **PEGATRON CORPORATION**, Taipei (TW)

(72) Inventors: **Chien-Yi Wu**, Taipei (TW); **Shih-Keng Huang**, Taipei (TW); **Sheng-Chin Hsu**, Taipei (TW); **Chao-Hsu Wu**, Taipei (TW); **Hau Yuen Tan**, Taipei (TW); **Tse-Hsuan Wang**, Taipei (TW); **Yi-Ru Yang**, Taipei (TW); **Cheng-Hsiung Wu**, Taipei (TW); **Ching-Hsiang Ko**, Taipei (TW)

(73) Assignee: **PEGATRON CORPORATION**, Taipei (TW)

(*) Notice: Subject to any disclaimer, the term of this patent is extended or adjusted under 35 U.S.C. 154(b) by 0 days.

(21) Appl. No.: **16/802,223**

(22) Filed: **Feb. 26, 2020**

(65) **Prior Publication Data**

US 2020/0358195 A1 Nov. 12, 2020

(30) **Foreign Application Priority Data**

May 9, 2019 (TW) 108116011

(51) **Int. Cl.**
H01Q 21/06 (2006.01)
H01Q 13/20 (2006.01)
H01Q 1/48 (2006.01)

(52) **U.S. Cl.**
CPC ***H01Q 13/206*** (2013.01); ***H01Q 1/48*** (2013.01); ***H01Q 21/065*** (2013.01)

(58) **Field of Classification Search**
CPC H01Q 21/065; H01Q 13/206; H01Q 1/38–1/48
See application file for complete search history.

(56) **References Cited**

U.S. PATENT DOCUMENTS

9,553,362	B2 *	1/2017	Inoue	H01Q 1/38
2018/0115084	A1 *	4/2018	Tsuchiya	H01Q 21/065
2019/0245276	A1 *	8/2019	Li	H01Q 21/065

FOREIGN PATENT DOCUMENTS

CN	203260725	10/2013
CN	106067605	9/2018
TW	494606	7/2002

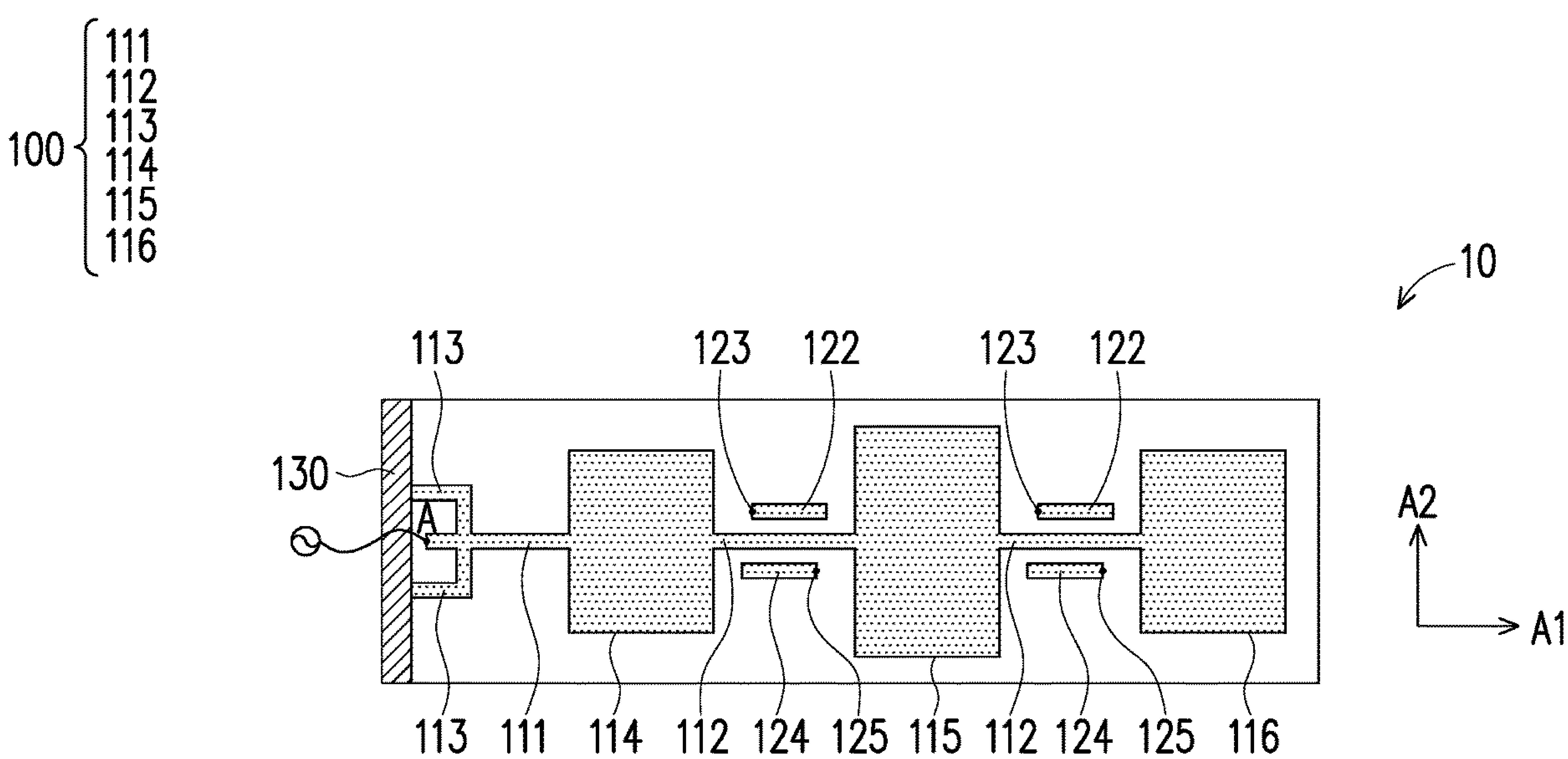
* cited by examiner

Primary Examiner — Hasam Islam
(74) *Attorney, Agent, or Firm* — J.C. Patents

(57) **ABSTRACT**

An antenna structure includes a ground plane and at least one series-fed antenna. Each series-fed antenna includes a first patch, a plurality of second patches, a first microstrip line, a first grounding structure group, a plurality of second microstrip lines, and a plurality of second grounding structure groups. The first patch is disposed beside the ground plane. The first patch and the second patch are arranged along a straight line. The first microstrip line extends from the first patch and has a feeding point. The first grounding structure group includes two first grounding traces that extend symmetrically from both sides of the first microstrip line to the ground plane. The second microstrip lines are respectively connected between the first patch and the second patches. The second grounding structure groups are respectively disposed on both sides of the second microstrip lines, and are coupled to the ground plane.

11 Claims, 9 Drawing Sheets



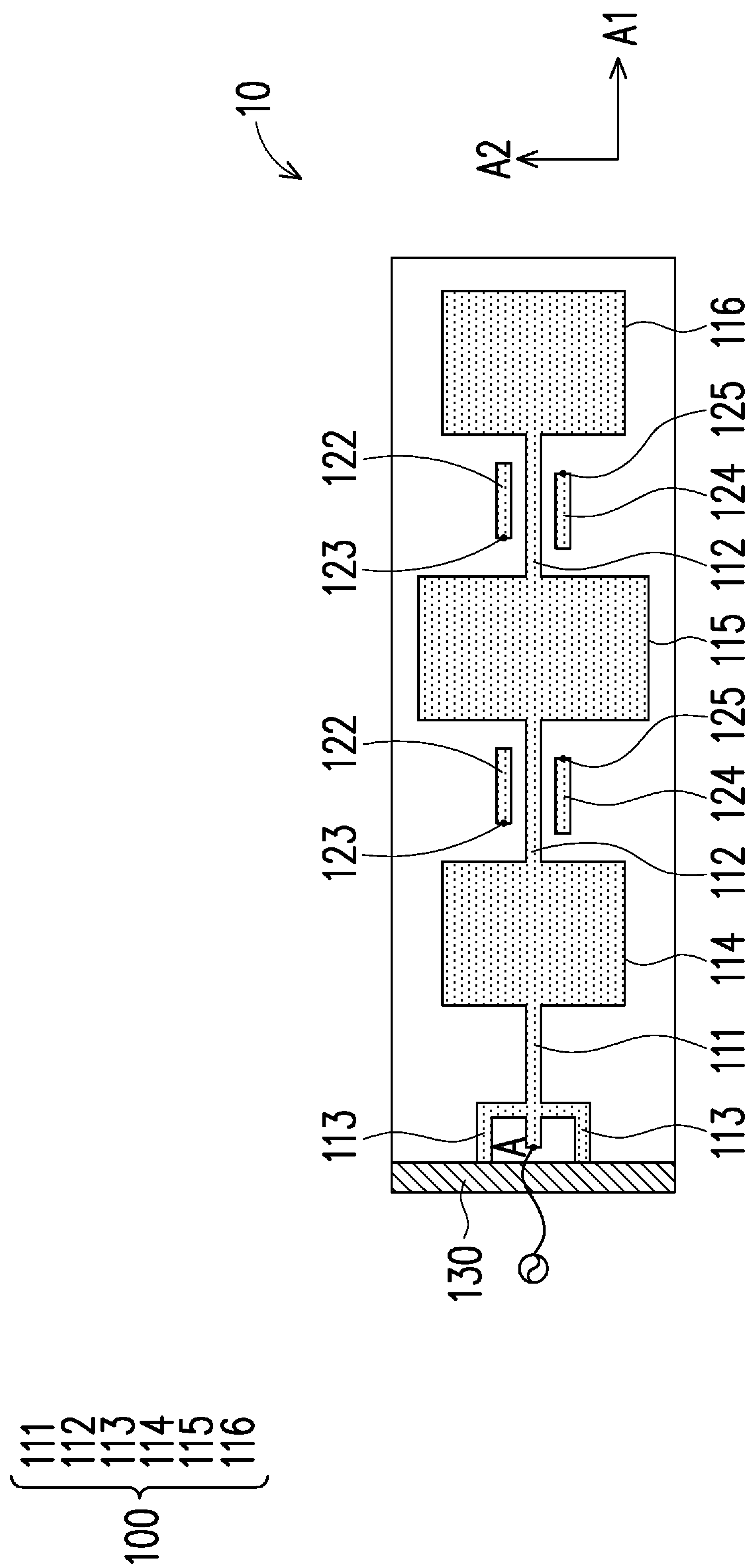

10
A1
A2
116
122
125
124
123
112
115
122
125
124
123
112
114
111
113
113
A
130
111
112
113
114
115
116
100

FIG. 1A

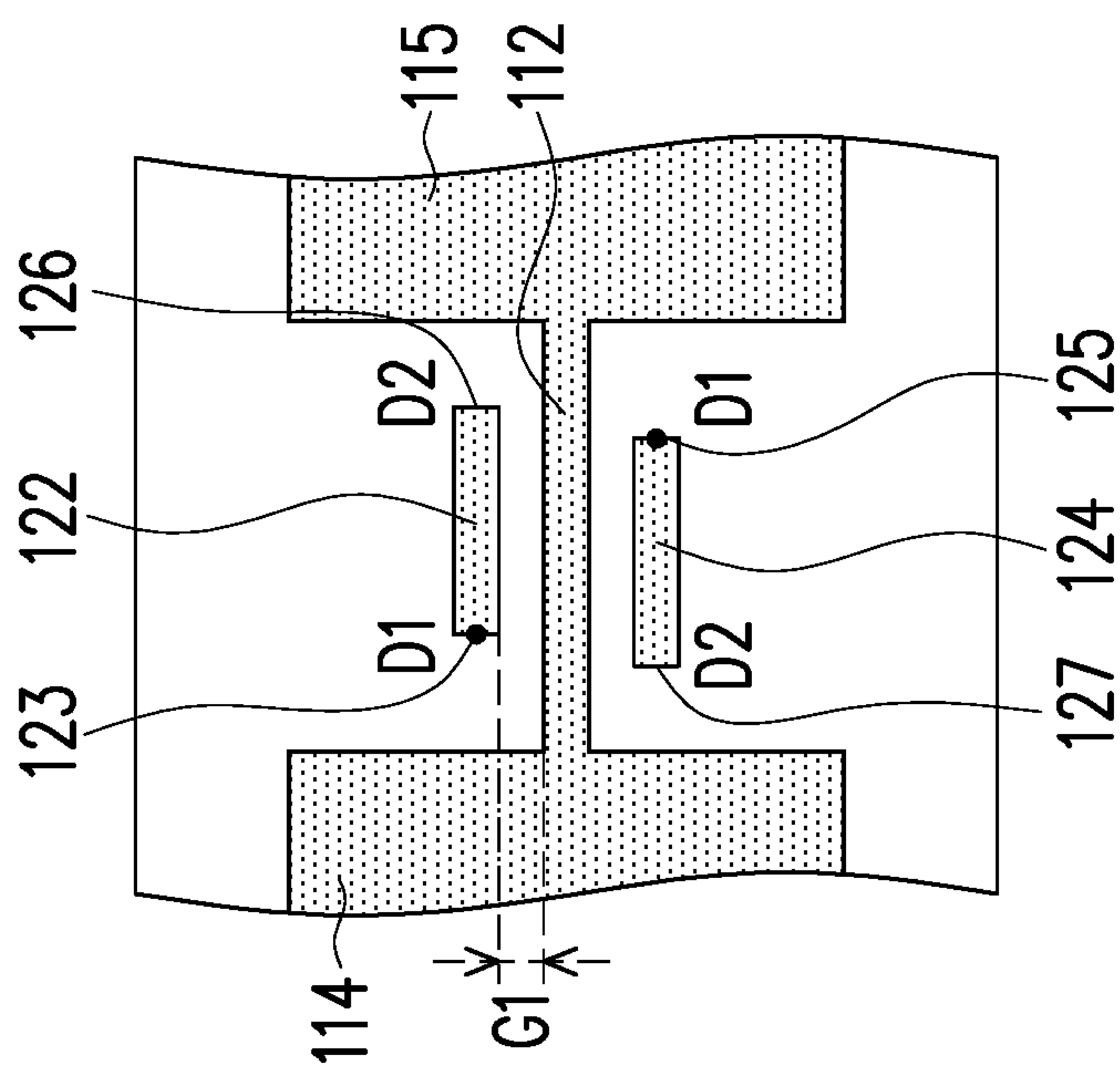

115
112
126
D2
D1
125
122
124
D1
D2
123
127
114
G1

FIG. 1C

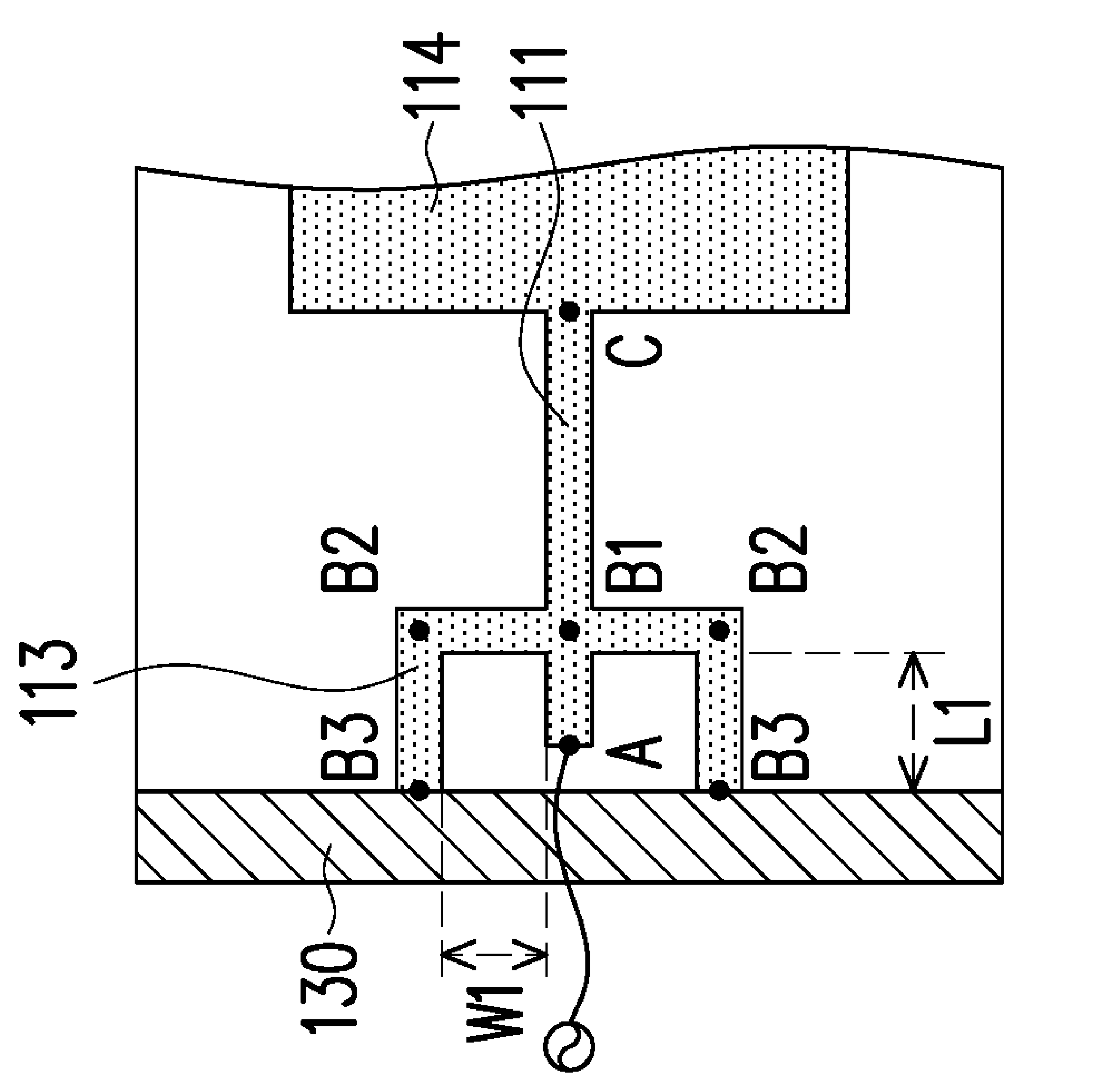

114
111
C
B2
B1
B2
113
B3
A
B3
L1
130
W1

FIG. 1B

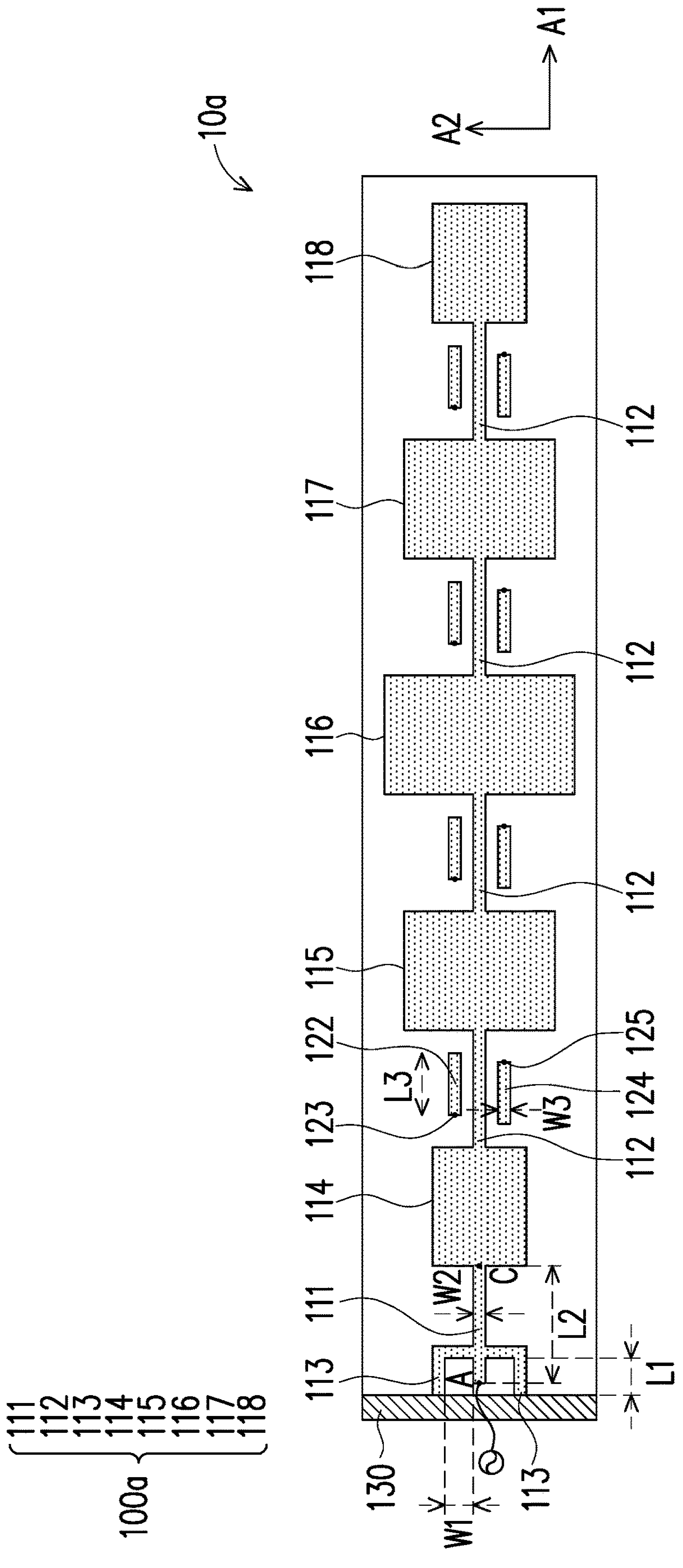

10a
A1
A2
118
112
117
112
116
112
115
122
125
L3
124
123
W3
112
114
W2
C
111
L2
113
A
L1
130
113
W1
100a
111
112
113
114
115
116
117
118

FIG. 2

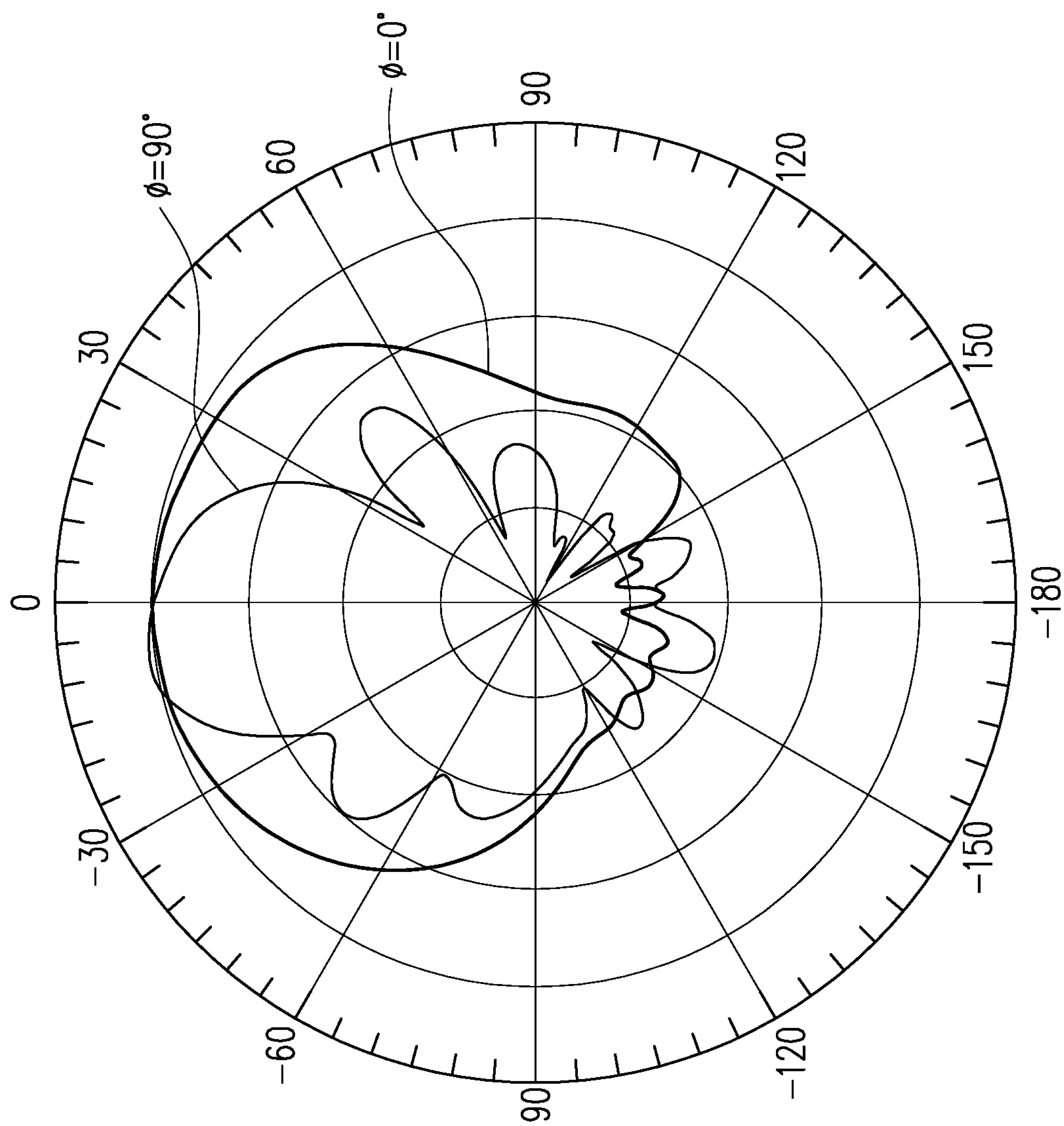


FIG. 3A

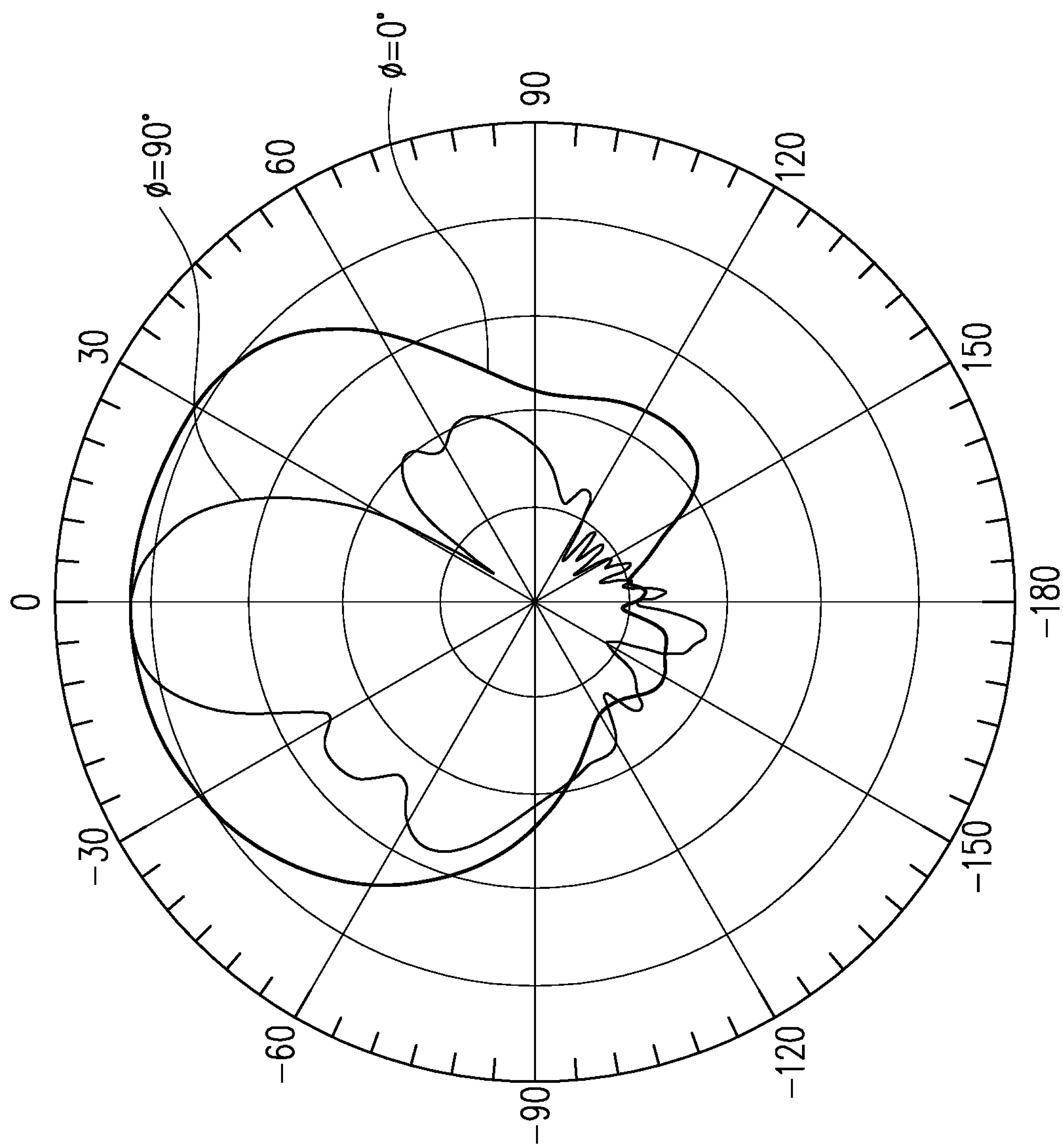


FIG. 3B

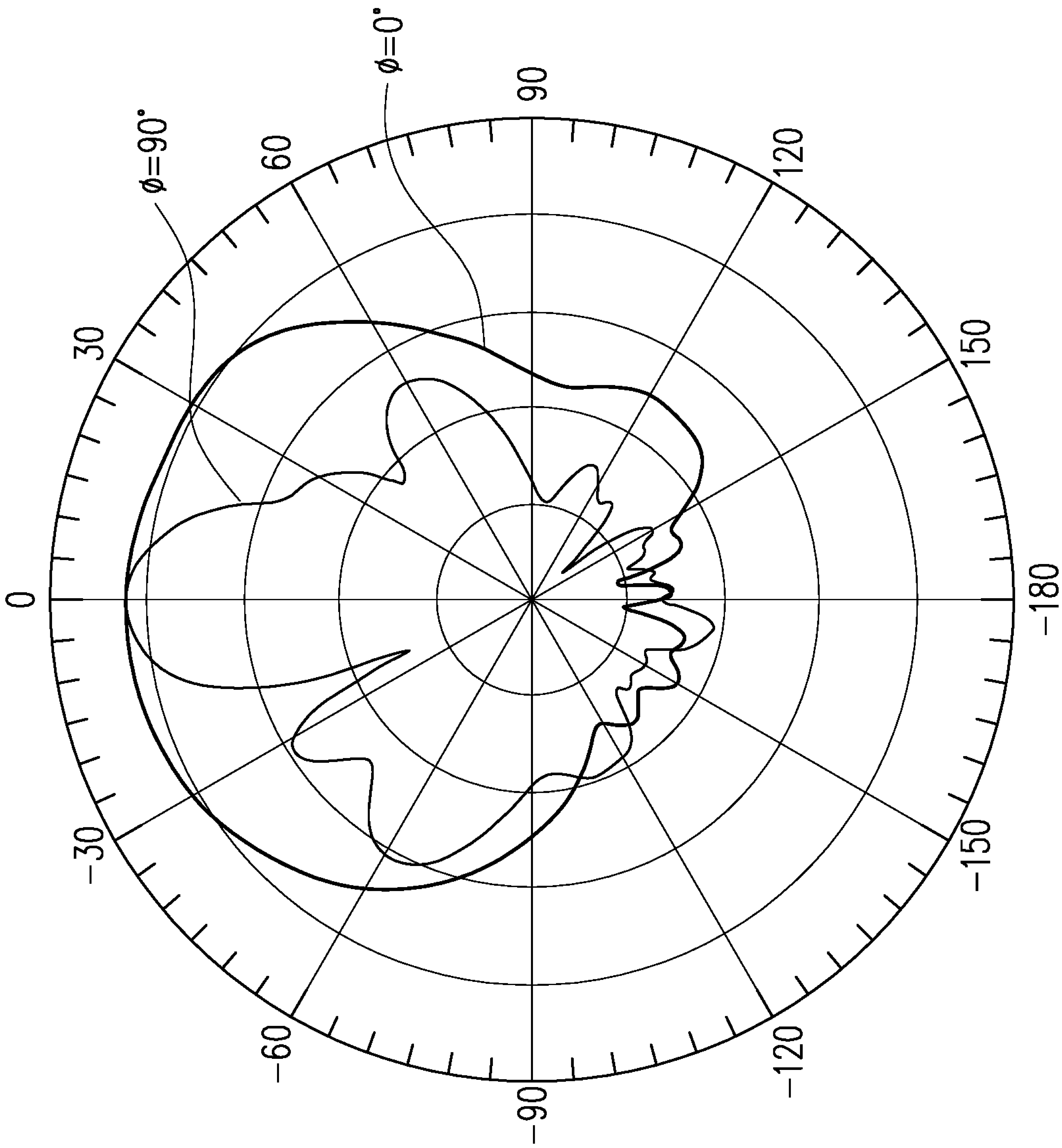


FIG. 3C

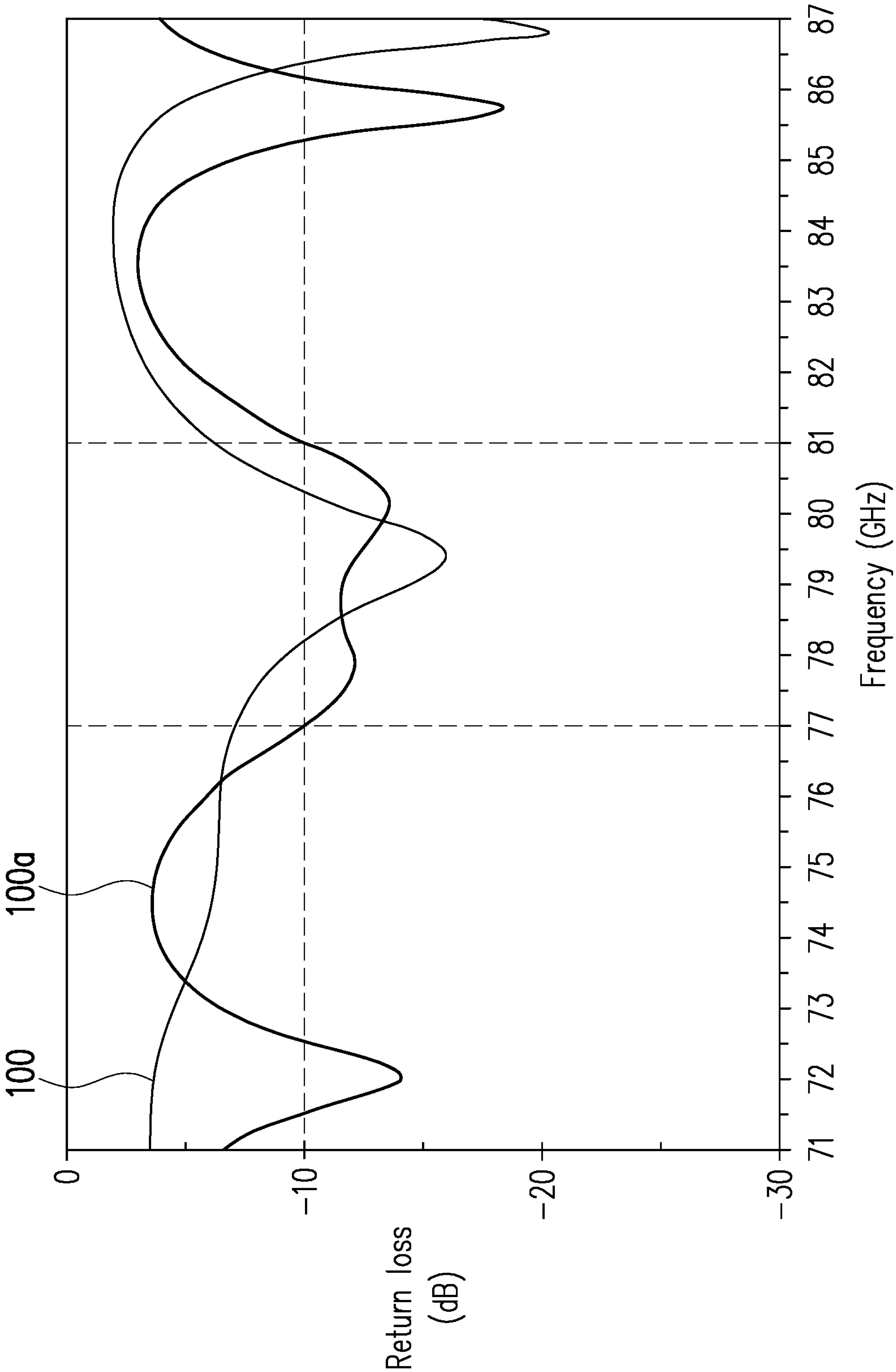

100
100a
Return loss
(dB)
0
−10
−20
−30
71
72
73
74
75
76
77
78
79
80
81
82
83
84
85
86
87
Frequency (GHz)

FIG. 4

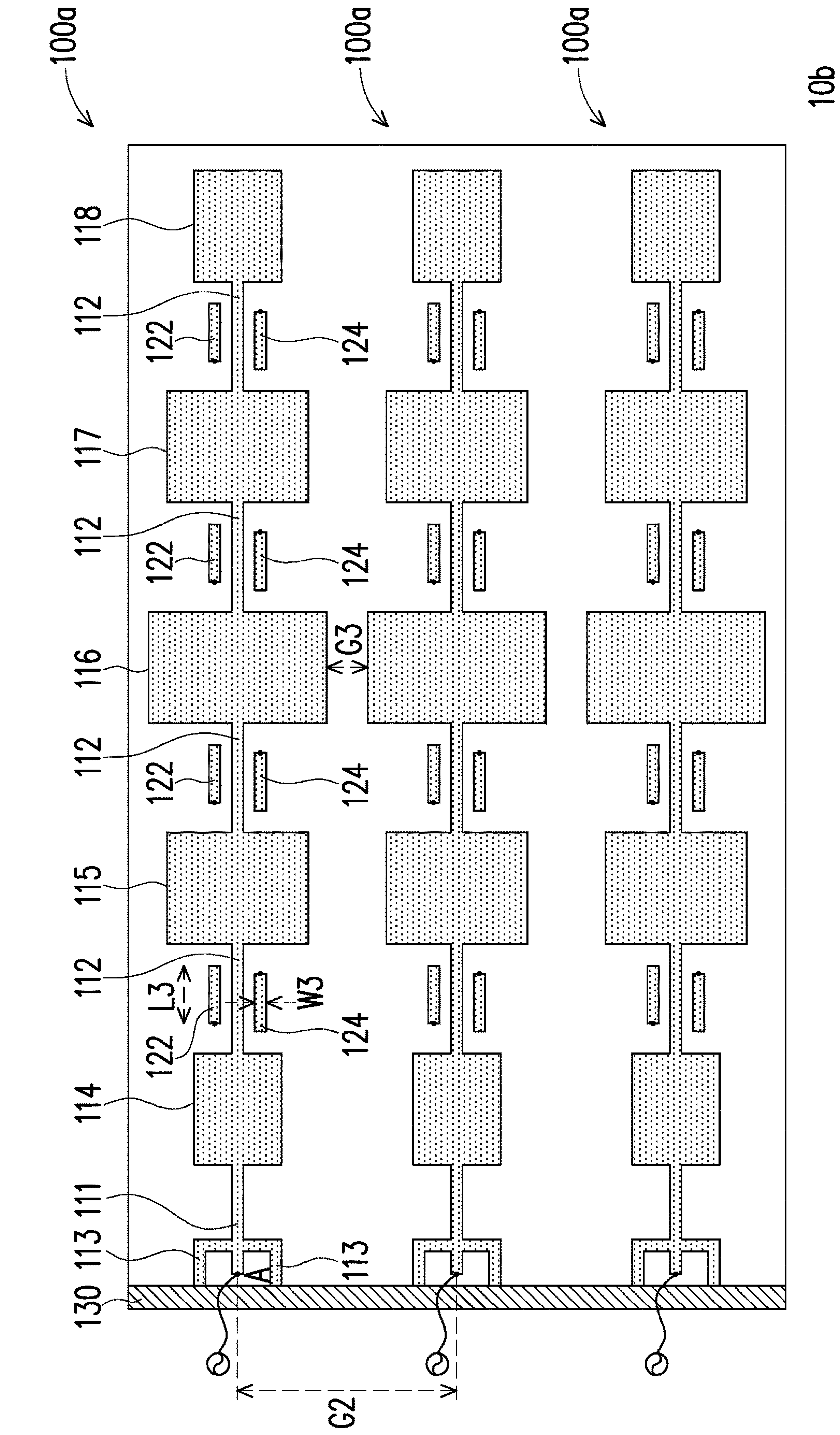

100a
100a
100a
10b
118
112
122
124
117
112
122
124
116
G3
112
122
124
115
112
L3
W3
122
124
114
111
113
113
A
130
G2

FIG. 5

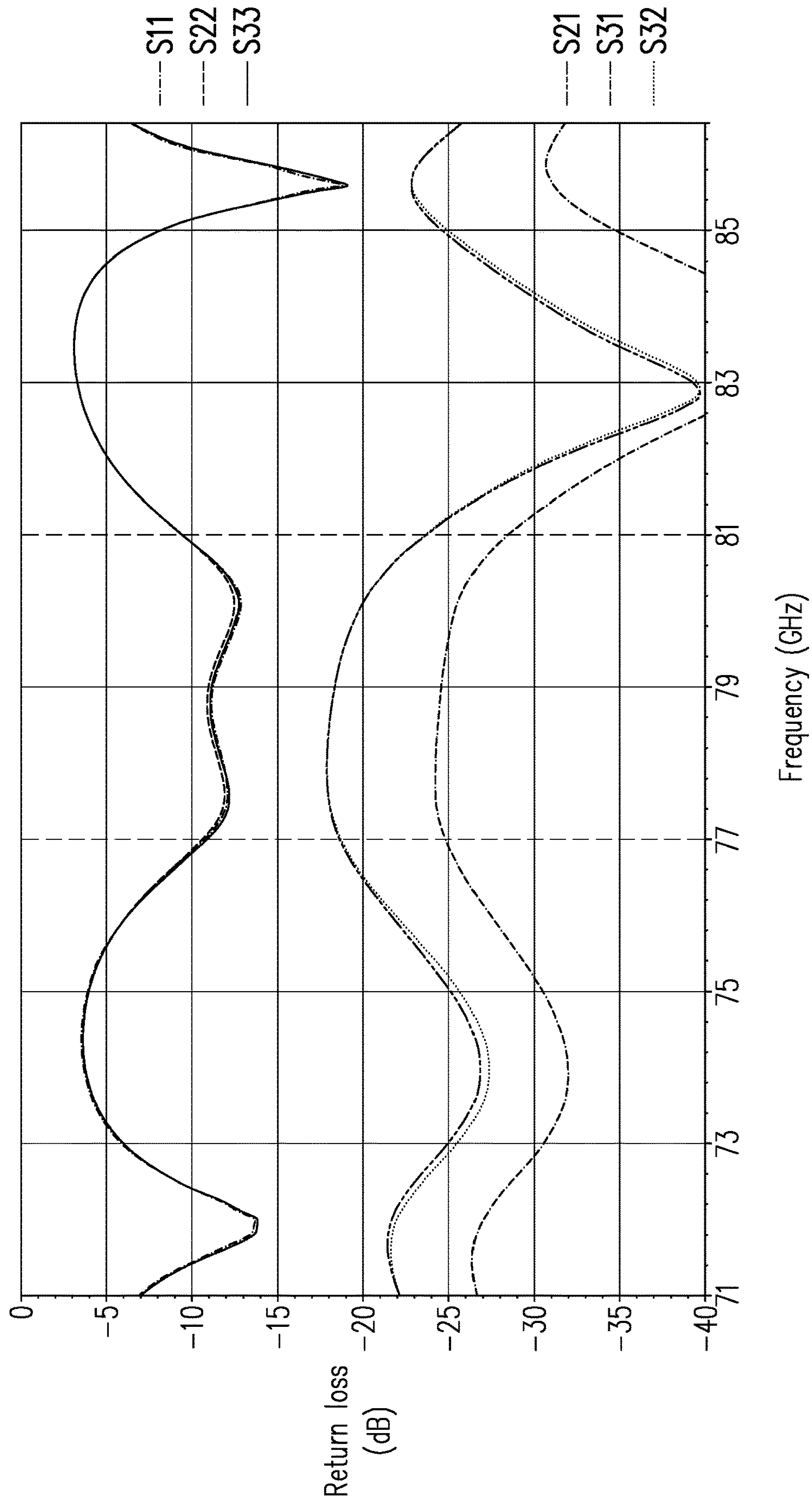

S11
S22
S33
S21
S31
S32
Return loss (dB)
Frequency (GHz)
0
−5
−10
−15
−20
−25
−30
−35
−40
71
73
75
77
79
81
83
85

FIG. 6

ANTENNA STRUCTURE

CROSS-REFERENCE TO RELATED APPLICATION

This application claims the priority benefit of Taiwan application serial no. 108116011, filed on May 9, 2019. The entirety of the above-mentioned patent application is hereby incorporated by reference herein and made a part of this specification.

BACKGROUND

Technical Field

The present disclosure relates to an antenna structure, and in particular, to a wideband antenna structure.

Related Art

Currently, a millimeter-wave radar applied to the automotive market has good signal penetration and high distance detection accuracy due to high operating frequencies (77 GHz and 79 GHz), and is applicable to a long distance detection system, such as an automatic emergency braking (AEB) system, an adaptive cruise (ACC) system, a forward collision prevention (FCW) system, etc. However, currently, most millimeter-wave radar antennas are designed in a general series-fed antenna form, and therefore a bandwidth thereof is limited by about 2%.

SUMMARY

The present disclosure provides an antenna structure that may have a wideband characteristic.

The antenna structure of the present disclosure includes a ground plane and at least one series-fed antenna. Each series-fed antenna includes a first patch, a plurality of second patches, a first microstrip line, a first grounding structure group, a plurality of second microstrip lines, and a plurality of second grounding structure groups. The first patch is disposed beside the ground plane. The first patch is arranged between the ground plane and the second patches, and the first patch and the second patches are arranged along a straight line. The first microstrip line extends from the first patch in a direction away from the second patches and has a first end and a second end opposite to each other. The first end is a feeding point, and the second end is connected to the first patch. The first grounding structure group includes two first grounding traces. The two first grounding traces extend symmetrically from opposite sides of the first microstrip line to the ground plane. The second microstrip lines are respectively connected between the first patch and the second patch adjacent to the first patch and connected between the second patches. The second grounding structure groups are respectively disposed on both sides of the second microstrip lines, and are coupled to ground plane.

Based on the above, in an embodiment of the present disclosure, in the antenna structure, the two grounding traces are symmetrically disposed on the two opposite sides of the first microstrip line and extend to the ground plane, and the second grounding structure groups are respectively disposed on both sides of the second microstrip lines and are coupled to the ground plane. According to a simulation result in the embodiment, through the above design, a range of a frequency band coupled out by the antenna structure and an impedance bandwidth can be increased, so that the antenna structure has a good antenna characteristic.

To make the features and advantages of the present disclosure clear and easy to understand, the following gives a detailed description of embodiments with reference to accompanying drawings.

BRIEF DESCRIPTION OF THE DRAWINGS

FIG. **1**A is a schematic diagram of an antenna structure according to an embodiment of the present disclosure.

FIG. **1**B and FIG. **1**C are respectively partial schematic enlarged views of an antenna structure in FIG. **1**A.

FIG. **2** is a schematic diagram of an antenna structure according to another embodiment of the present disclosure.

FIG. **3**A to FIG. **3**C are radiation pattern diagrams corresponding to an antenna structure in FIG. **2** at three frequency points of 77 GHz, 79 GHz, and 81 GHz.

FIG. **4** is a diagram of frequency-return loss relationships of an antenna structure in FIG. **1**A and an antenna structure in FIG. **2**.

FIG. **5** is a schematic diagram of an antenna structure according to another embodiment of the present disclosure.

FIG. **6** is a diagram of a frequency-return loss relationship of an antenna structure in FIG. **5**.

DETAILED DESCRIPTION

FIG. **1**A is a schematic diagram of an antenna structure according to an embodiment of the present disclosure. FIG. **1**B and FIG. **1**C are respectively partial schematic enlarged views of an antenna structure in FIG. **1**A. Referring to FIG. **1**A to FIG. **1**C, an antenna structure **10** in this embodiment includes a ground plane **130** and at least one series-fed antenna **100**. In this embodiment, that the antenna structure **10** has one series-fed antenna **100** is used as an example, but a number of the series-fed antennas **100** is not limited thereto. In this embodiment, the series-fed antenna **100** includes a first patch **114**, a plurality of second patches **115** and **116**, a first microstrip line **111**, a first grounding structure group (two first grounding traces **113**), a plurality of second microstrip lines **112**, and a plurality of second grounding structure groups (two second grounding traces **122** and **124**).

As shown in FIG. **1**A, in this embodiment, the first patch **114** is disposed beside the ground plane **130**. The first patch **114** is arranged between the ground plane **130** and the second patches **115** and **116**, and in particular, the first patch **114** is arranged between the ground plane **130** and the second patch adjacent to the first patch **114** (i.e., the second patch **115**). The first patch **114** and the second patches **115** and **116** are arranged along one straight line. In this embodiment, there are two second patches **115** and **116**, but a number of the second patches **115** and **116** is not limited thereto.

In this embodiment, an area of the first patch **114** and areas of the second patches **115** and **116** increase and then decrease along a direction (a direction A**1**) in which the straight line extends. The area of the first patch **114** is the same as an area of the second patch **116** far away from the first patch **114** and less than an area of the second patch **115** adjacent to the first patch **114**. In other words, the series-fed antenna **100** is a patch antenna assembled in a tapered manner. Definitely, in other embodiments, the area of the first patch **114** may be the same as the area of each of the second patches **115** and **116**. An area relationship between the first patch **114** and the second patches **115** and **116** is not limited thereto.

In addition, in this embodiment, the first patch **114** and each of the second patches **115** and **116** are rectangular. One side length (for example, a side length along the direction A**1**) of any of the first patch **114** and the second patches **115** and **116** is between 0.9 millimeters and 1.05 millimeters, and another side length (for example, a side length along a direction A**2**) is between 0.7 millimeters and 1.6 millimeters. Definitely, a relationship between dimensions of the first patch **114** and the second patches **115** and **116** is not limited thereto.

The first microstrip line **111** extends from the first patch **114** in a direction away from the second patches **115** and **116**. More specifically, as shown in FIG. **1**B, the first microstrip line **111** has a first end A and a second end C opposite to each other. The first end A is a feeding point, and the second end C is connected to the first patch **114**. There is a distance between the first end A of the first microstrip line **111** and the ground plane **130** without contacting the ground plane **130**. In this embodiment, the antenna structure **10** is adapted to couple out a frequency band ranging from about 77 GHz to 81 GHz, but the range of the frequency band is not limited thereto. A length of the first microstrip line **111** (that is, a distance between the first end A and the second end C) is between 0.39 times and 0.42 times a wavelength of the frequency band.

As shown in FIG. **1**B, in this embodiment, the first grounding structure group includes two first grounding traces **113** that extend symmetrically from two opposite sides of the first microstrip line **111** to the ground plane **130**. In each series-fed antenna **100**, a length of the first grounding trace **113** is between 0.22 times and 0.28 times the wavelength of the frequency band, for example, 0.25 times the wavelength.

In this embodiment, the first grounding trace **113** includes a first segment (that is, a line segment B**1**B**2**) and a second segment (that is, a line segment B**2**B**3**) connected in a bent manner. The first segment (the line segment B**1**B**2**) extends vertically from the first microstrip line **111**, and the second segment (the line segment B**2**B**3**) is parallel to the first microstrip line **111** and connected to the ground plane **130**. A distance L**1** between the first segment (the line segment B**1**B**2**) and the ground plane **130** is between 0.2 millimeters and 0.4 millimeters. It is worth mentioning that after simulation, when the distance L**1** between the first segment (the line segment B**1**B**2**) and the ground plane **130** is gradually changed from 0.2 millimeters to 0.3 millimeters and 0.4 millimeters, a Smith chart of the antenna structure **10** has a clockwise rotation characteristic. When the distance L**1** between the first segment (the line segment B**1**B**2**) and the ground plane **130** is 0.3 millimeters, a frequency band of the first grounding trace **113** may range from 77 GHz to 81 GHz, and therefore has good performance.

In addition, when the first segment (the line segment B**1**B**2**) or the second segment (the line segment B**2**B**3**) of the first grounding trace **113** widens outward, for example, the line segment B**1**B**2** of the first grounding trace **113** is thickened rightward by 0.1 millimeters, 0.2 millimeters, and 0.3 millimeters, the upper line segment B**2**B**3** is thickened upward by 0.1 millimeters, 0.2 millimeters, and 0.3 millimeters, and the lower line segment B**2**B**3** is thickened downward by 0.1 millimeters, 0.2 millimeters, and 0.3 millimeters, the Smith chart of the antenna structure **10** has a clockwise rotation characteristic. When the second segment (the line segment B**2**B**3**) of the first grounding trace **113** is widened inward, for example, the upper line segment B**2**B**3** of the first grounding trace **113** is thickened downward by 0.1 millimeters, 0.15 millimeters, and 0.2 millimeters, and the lower line segment B**2**B**3** is thickened upward by 0.1 millimeters, 0.15 millimeters, and 0.2 millimeters, the Smith chart of the antenna structure **10** has a counterclockwise rotation characteristic. A designer may adjust a dimension of the first grounding trace **113** according to the above characteristics to obtain good antenna performance.

In addition, in this embodiment, a distance W**1** between the second segment (the line segment B**2**B**3**) and the first microstrip line **111** is between 0.2 millimeters and 0.25 millimeters. It is worth mentioning that after simulation, the distance W**1** between the second segment (the line segment B**2**B**3**) and the first microstrip line **111** is gradually changed from 0.2 millimeters to 0.23 millimeters, and 0.25 millimeters. Therefore, the Smith chart of the first grounding trace **113** has a clockwise rotation characteristic. When the distance W**1** between the second segment (the line segment B**2**B**3**) and the first microstrip line **111** is 0.2 millimeters, an impedance matching effect at 77 GHz to 79 GHz is better. When the distance W**1** between the second segment (the line segment B**2**B**3**) and the first microstrip line **111** is 0.25 millimeters, an impedance matching effect at 79 GHz to 81 GHz is better. When the distance W**1** between the second segment (the line segment B**2**B**3**) and the first microstrip line **111** is 0.23 millimeters, the first grounding trace **113** may have a frequency ranging from 77 GHz to 81 GHz, and therefore has wideband performance. Definitely, the distances L**1** and W**1** are not limited thereto.

Returning back to FIG. **1**A, in this embodiment, there are two second microstrip lines **112** corresponding to the two second patches **115** and **116**. However, a number of the second microstrip lines **112** is not limited thereto. The second microstrip lines **112** are respectively connected between the first patch **114** and the second patch **115** adjacent to the first patch **114** and connected between the second patches **115** and **116**. In addition, in this embodiment, the second microstrip lines **112** have a same length. However, in other embodiments, the second microstrip lines **112** may have different lengths.

In addition, in this embodiment, there are two second grounding structure groups corresponding to the two second microstrip lines **112**, but a number of the second grounding structure groups is not limited thereto. The two second grounding structure groups are respectively disposed on both sides of the two second microstrip lines **112**. Each of the second grounding structure groups includes two second grounding traces **122** and **124** symmetrically arranged on two opposite sides of the corresponding second microstrip line **112** and are respectively connected to the ground plane **130**. The second grounding traces **122** and **124** are, for example, connected to a ground terminal located on a back surface of a substrate through a through hole, and are coupled to the ground plane **130**.

As shown in FIG. **1**C, in this embodiment, in each of the grounding structure groups, each of the second grounding traces **122** and **124** includes a first end **123** and **125** and a second end **126** and **127** respectively. In each of the grounding structure groups, the first end **123** and the second end **126** of the second grounding trace **122** respectively correspond to the second end **127** and the first end **125** of the second grounding trace **124**, and the two first ends **123** and **125** are coupled to the ground plane to serve as two grounding terminals. In other words, the first end **123** of the second grounding trace **122** and the first end **125** of the second grounding trace **124** are respectively close to two opposite ends of the corresponding second microstrip line **112**. In the design of grounding on the opposite sides, the Smith chart may be slightly smaller and an impedance bandwidth may be increased. Definitely, in other embodiments, relative positions of the first end **123** of the second grounding trace **122** and the first end **125** of the second grounding trace **124** are not limited thereto.

In addition, in this embodiment, a length of the second grounding traces **122** and **124** (that is, a distances between positions D**1** and D**2** in FIG. **1**C) is between 0.2 times and 0.3 times the wavelength of the frequency band. For example, lengths of the second grounding traces **122** and **124** are between 0.65 millimeters and 0.85 millimeters, and widths of the second grounding traces **122** and **124** are between 0.08 millimeters and 0.12 millimeters. Definitely, the lengths and the widths of the second grounding traces **122** and **124** are not limited thereto. When the length (a line segment D**1**D**2**) of the second grounding traces **122** and **124** is gradually changed from 0.577 millimeters to 0.677 millimeters and 0.777 millimeters, it may be learned from the Smith chart that an impedance circle becomes larger and a frequency tends to be low. In this embodiment, when the lengths (the line segment D**1**D**2**) of the second grounding traces **122** and **124** are 0.777 millimeters, the second grounding traces **122** and **124** may have a frequency band ranging from 77 GHz to 81 GHz, and therefore have a relatively large impedance bandwidth.

In addition, in this embodiment, a distance G**1** between the second microstrip line **112** and the second grounding traces **122**, which is the same as the distance between the second microstrip line **112** and the second grounding traces **124**, is between 0.08 millimeters and 0.12 millimeters, for example, is 0.1 millimeters, but the distance G**1** is not limited thereto.

In this embodiment, in the antenna structure **100**, the two first grounding traces **113** are symmetrically disposed on the two opposite sides of the first microstrip line **111** and extend to the ground plane **130**, and the two second grounding traces **122** and **124** are symmetrically disposed on two opposite sides of the second microstrip line **112** and grounded in different directions respectively. According to a simulation result in the embodiment, through the above design, a range of a frequency band coupled out by the antenna structure **10** and an impedance bandwidth can be increased, so that the antenna structure **10** has a good antenna characteristic.

FIG. **2** is a schematic diagram of an antenna structure according to another embodiment of the present disclosure. Referring to FIG. **2**, a main difference between an antenna structure **10***a* in FIG. **2** and the antenna structure **10** in FIG. **1**A is that in this embodiment, a series-fed antenna **100***a* includes second patches **115**, **116**, **117**, and **118**. In other words, there are four second patches **115**, **116**, **117**, and **118**. There are four second microstrip lines **112**, and there are four second grounding structure groups.

In this embodiment, an area of the first patch **114** and areas of the second patches **115**, **116**, **117**, and **118** increase and then decrease along a direction (a direction A**1**) in which the straight line extends. More specifically, the second patch **116** at a central position has a largest area, the second patch **115** and the second patch **117** have second largest areas, and the first patch **114** and the second patch **118** have smallest areas. In this embodiment, the area of the first patch **114** is the same as the area of the second patch **118** farthest away from the first patch **114**, the area of the second patch **115** is the same as the area of the second patch **117**, and the area of first patch **114** is a half of the area of the second patch **116** at the central position.

In particular, in this embodiment, a dimension of the antenna structure **10***a* is 9.65 millimeters×1.57 millimeters×0.102 millimeters (which is a thickness of a substrate). A side length of the first patch **114** along the direction A**1** is, for example, 0.96 millimeters, which is 0.416 times the wavelength of the frequency band coupled out by the antenna structure **10***a*. The side length of the first patch **114** along the direction A**2** is, for example, 0.785 millimeters. A length of the first microstrip line **111** is 0.955 millimeters, which is 0.41 times the wavelength of the frequency band (77 GHz to 81 GHz) coupled out by the antenna structure **10***a*. A width of the first microstrip line **111** is 0.1 millimeters.

Side lengths of the second patches **115**, **116**, **117**, and **118** along the direction A**1** are, for example, 0.96 millimeters, which is 0.416 times the wavelength of the frequency band coupled out by the antenna structure **10***a*. The side lengths of the second patches **115**, **116**, **117**, and **118** along the direction A**2** are, for example, 1.24 millimeters, 1.57 millimeters, 1.24 millimeters, and 0.785 millimeters. A length of the second microstrip line **112** is 0.95 millimeters, which is 0.39 times the wavelength of the frequency band coupled out by the antenna structure **10***a*. A width of the second microstrip line **112** is 0.1 millimeters. Lengths of the second grounding traces **122** and **124** are about 0.777 millimeters and widths of the second grounding traces **122** and **124** are about 0.1 millimeters.

In this embodiment, through the first grounding structure group, a bandwidth of a frequency band coupled out by the antenna structure **10***a* can be increased to 4.82%. In this embodiment, through the second grounding structure group, the bandwidth of the frequency band coupled out by the antenna structure **10***a* can be increased to 5.06%. The antenna structure **10***a* can have a maximum gain from 11.09 dBi to 12.4 dBi at the frequency band of 77 GHz to 81 GHz.

FIG. **3**A to FIG. **3**C are radiation pattern diagrams corresponding to an antenna structure in FIG. **2** at different frequency points of 77 GHz, 79 GHz, and 81 GHz. Referring to FIG. **3**A to FIG. **3**C, in this embodiment, maximum values of the antenna structure **10***a* in FIG. **2** in a field pattern in which ψ is 0° and in a field pattern in which ψ is 90° are both at a position of zero degrees on a Z axis, so that a mainlobe is more likely to aim at the zero degrees on the Z axis. In such a design, a sidelobe is about 10 dB lower than the mainlobe, so that a characteristic of the sidelobe is suppressed. Therefore, performance is good.

FIG. **4** is a diagram of frequency-return loss relationships of an antenna structure in FIG. **1**A and an antenna structure in FIG. **2**. Referring to FIG. **4**, the antenna structure **10** in FIG. **1**A and the antenna structure **10***a* in FIG. **2** both have a resonance frequency band at 77 GHz to 79 GHz, and a return loss at the frequency band from 77 GHz to 81 GHz can be less than −10 dB. Therefore, performance is good. The antenna structure **10***a* in FIG. **2** has two valleys in the resonance frequency band at 77 GHz to 79 GHz, and a junction of the two valleys is 79 GHz. A current return loss can be increased to 11.6 dB, and the bandwidth can be synchronously increased to 5.06%.

FIG. **5** is a schematic diagram of an antenna structure according to another embodiment of the present disclosure. In particular, a multi-antenna arrangement structure is shown. Referring to FIG. **5**, in this embodiment, an antenna structure **10***b* includes a plurality of series-fed antennas **100***a* disposed beside the ground plane **130** side by side. The series-fed antenna **100***a* is the series-fed antenna **100***a* in FIG. **2** as an example. The series-fed antenna **100***a* has four second patches **115**, **116**, **117**, and **118**. However, in other embodiments, a number of the second patches of the series-fed antenna **100***a* is not limited thereto. In addition, in this embodiment, for example, there are three series-fed antennas **100***a*, but a number of the series-fed antennas **100***a* is not limited thereto.

As shown in FIG. **5**, in this embodiment, a distance G**2** between two feeding points of two adjacent ones of the series-fed antennas **100***a* is between 1.7 millimeters and 2.1 millimeters, for example, 1.9 millimeters. In addition, a minimum distance G**3** between two adjacent ones of the series-fed antennas **100***a* is between 0.29 millimeters and 0.37 millimeters, for example, 0.33 millimeters. In this embodiment, when the series-fed antennas **100***a* are disposed at a transmitter end or a receiver end, the minimum distance G**3** in the range can meet all antenna characteristics of each of the series-fed antennas **100***a*.

FIG. **6** is a diagram of a frequency-return loss relationship of an antenna structure in FIG. **5**. Referring to FIG. **6**, in this embodiment, if an uppermost series-fed antenna **100***a* in FIG. **5** is used as a first series-fed antenna **100***a*, a central series-fed antenna **100***a* is used as a second series-fed antenna **100***a*, and a lowermost series-fed antenna **100***a* is used as a third series-fed antenna **100***a*, it may be learned from FIG. **6** that return losses S**11**, S**22**, and S**33** of the three series-fed antennas **100***a* at the frequency band from 77 GHz to 81 GHz are all less than −10 dB. Therefore, performance is good. In addition, isolations S**21**, S**32**, and S**31** between two adjacent series-fed antennas **100***a* can be below −17.9 dB, and therefore the isolation is good.

In summary, in an embodiment of the present disclosure, in the antenna structure, the two first grounding traces are symmetrically disposed on the two opposite sides of the first microstrip line and extend to the ground plane, and the two second grounding traces are symmetrically disposed on two opposite sides of the second microstrip line and grounded in different directions respectively. After test, through the above design, a range of a frequency band coupled out by the antenna structure and an impedance bandwidth can be increased, so that the antenna structure has a good antenna characteristic.

Although the present disclosure is described with reference to the above embodiments, the embodiments are not intended to limit the present disclosure. A person of ordinary skill in the art may make variations and modifications without departing from the spirit and scope of the present disclosure. Therefore, the protection scope of the present disclosure should be subject to the appended claims.

What is claimed is:

1. An antenna structure, comprising:

a ground plane; and

at least one series-fed antenna comprising:

a first patch;

a plurality of second patches, wherein the first patch is arranged between the ground plane and the second patches, and the first patch and the second patches are arranged along a straight line;

a first microstrip line extending from the first patch in a direction away from the second patches and having a first end and a second end opposite to each other, wherein the first end is a feeding point, and the second end is connected to the first patch;

a first grounding structure group comprising two first grounding traces, wherein the two first grounding traces extend symmetrically from opposite sides of the first microstrip line to the ground plane;

a plurality of second microstrip lines respectively connected between the first patch and the second patch adjacent to the first patch and connected between the second patches; and

a plurality of second grounding structure groups respectively disposed on both sides of the second microstrip lines and coupled to the ground plane.

2. The antenna structure according to claim **1**, wherein each of the second grounding structure groups comprises two second grounding traces symmetrically disposed on the both sides of the corresponding second microstrip line, each of the second grounding traces comprises a first end and a second end, and in each of the second grounding structure groups, the first end and the second end of one of the second grounding traces respectively correspond to the second end and the first end of another of the second grounding traces, and the two first ends are coupled to the ground plane.

3. The antenna structure according to claim **1**, wherein in each of the series-fed antennas, an area of the first patch and areas of the second patches increase and then decrease along a direction in which the straight line extends.

4. The antenna structure according to claim **1**, wherein in each of the series-fed antennas, there are two second patches, and there are two second microstrip lines, an area of the first patch is the same as an area of the second patch far away from the first patch and less than an area of the second patch adjacent to the first patch.

5. The antenna structure according to claim **1**, wherein in each of the series-fed antennas, there are four second patches, and there are four second microstrip lines, an area of the first patch is the same as an area of the second patch farthest away from the first patch and is a half of an area of the second patch at a central position.

6. The antenna structure according to claim **1**, wherein each of the first grounding traces comprises a first segment and a second segment connected in a bent manner, the first segment extends vertically from the first microstrip line, and the second segment is parallel to the first microstrip line and is connected to the ground plane.

7. The antenna structure according to claim **1**, wherein the antenna structure is adapted to couple out a frequency band, in each of the series-fed antennas, a length of each of the first grounding traces is between 0.22 times and 0.28 times a wavelength of the frequency band.

8. The antenna structure according to claim **1**, wherein the antenna structure is adapted to couple out a frequency band, in each of the series-fed antennas, a length of the first microstrip line is 0.39 times to 0.42 times a wavelength of the frequency band.

9. The antenna structure according to claim **1**, wherein the antenna structure is adapted to couple out a frequency band, in each of the series-fed antennas, a length of each of the second microstrip lines is 0.39 times to 0.42 times a wavelength of the frequency band.

10. The antenna structure according to claim **1**, wherein the antenna structure is adapted to couple out a frequency band, in each of the series-fed antennas, each of the second grounding structure groups comprising two second grounding traces, a length of each of the second grounding traces is 0.2 times to 0.3 times a wavelength of the frequency band.

11. The antenna structure according to claim **1**, wherein the at least one series-fed antenna comprises a plurality of series-fed antennas disposed beside the ground plane side by side, a minimum distance between adjacent ones of the series-fed antennas is between 0.29 millimeters and 0.37 millimeters, and a distance between two feeding points of two adjacent ones of the series-fed antennas is between 1.7 millimeters and 2.1 millimeters.

* * * * *